

FILTRATION MEDIA AND THE MANUFACTURE THEREOF

This invention relates to the manufacture of filtration media and in particular to the manufacture of electrostatic filtration media suitable *inter alia* for respiratory
5 filtration applications, and to novel filtration media produced thereby.

Filtration media are widely used in many applications, for example for the capture of airborne particles (bacteria, dust etc). In such filters it is desirable for the resistance to airflow to be low, without sacrificing the filtration efficiency (ie the
10 effectiveness with which the filter captures the airborne particles). A known measure intended to achieve these objectives is the creation of electrostatic charge on the filter material. Such a charge serves to attract the airborne material. One particular field of application of such electrostatically-charged filter media is respiratory filtration.

15 US 4,798,850 describes the formation of filter material with a felt structure composed of a blend of clean polypropylene fibres and clean fibres of an addition polymer comprising one or more halogen-substituted hydrocarbons. The felt is made by carding fibres into a web and needling them to form a coherent fabric
20 structure.

In the carding operation, fibres are worked by a series of toothed rollers, which serve to disentangle the fibre and provide some mixing to increase the homogeneity of the blend. The product from the carding machine is a continuous
25 web, which is peeled from the last main roller on the machine (doffer). The orientation of fibres in the web leaving the doffer is substantially dictated by the orientation of fibres leaving the doffer and is predominantly in the machine direction. In carding, the assembly of the web takes place mainly on the doffer and fibres are controlled by fibre to metal friction in the machine. The web is
30 subsequently layered to produce a so-called batt structure that is then mechanically bonded.

In general, it is desirable to be able to produce filtration media having satisfactory filtration efficiencies and low resistance to airflow, without having excessively high weight or thickness. It is also desirable to be able to achieve these objectives without having to resort to multi-layer structures in which the filtration medium is
5 laminated with, or bonded to, other material.

There has now been devised an improved method of forming non-woven filter materials which offers significant advantages over the prior art.

10 According to the invention, there is provided a process for the manufacture of a filtration medium, which process comprises air-laying fibres to form a non-woven web.

The process according to the invention is advantageous over the prior art in
15 several respects, including the following:

- (i) The fibre orientation in the web is more random (owing to the dispersion of loose fibres in air immediately before web formation). Web properties are consequently more isotropic.
- (ii) No carding step is required (as compared to the prior art) and consequently
20 the resulting structure does not consist of individual layers of web assembled one on top of the other. A single integrated structure is produced.
- (iii) The air-laid web structure can be characterised by pronounced orientation in the z-direction (or perpendicular to the web surface). This gives the structure higher bulk (for a given area density) than a carded web.
- 25 (iv) Using the sifting air-lay approach, fibres of 2-12mm can be converted into uniform web structures (in contrast to the prior art, which permits only lengths of typically 30-200mm to be processed (due to restrictions imposed by carding)).
- (v) A shorter web formation process is achieved as compared to carding.
- (vi) Providing it is clean, short, waste fibres (eg polypropylene) can be used in
30 the process assuming the length is at least 2mm. Such short fibres are incompatible with the carding process.

In the air-laying process, the manner of web formation is substantially different from the prior art and marked differences in fabric properties are obtained. In air-laying, fibres are transferred to either

- 5 (a) a rapidly rotating cylinder or roller clothed with teeth and interacting with either other toothed rollers or fixed carding plates or
- (b) a sifting screen or rotor device in which fibres are circulated over a mesh screen and then passed through an air-stream to form a web structure.

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The former approach (roller-based air-laying) is presently preferred. In both processes, the mechanical working treatment is much shorter than that used in carding but is sufficient to electrostatically charge the fibre. In contrast to carding, the effect can be created solely at the site of interaction between the feed rollers and the opening roller. No further working points (eg worker rollers) are required. Electrostatic charging of the fibres is believed to be achieved as the fibres are separated between a set of feed rollers and a single rapidly rotating roller, or as they are contacted by the rotors and mesh yarns of the grid. Multiple rollers as used in carding are not required. In further contrast to carding, the charged fibres are then dispersed freely in a moving air stream to form an air/fibre mixture. The air then transports fibres from the rotating cylinder (or sifting area) to a suctioned mesh conveyor belt, screen or drum where the fibres are landed to form the web. The belt/drum acts as an air/fibre separator. The process is continuous and web weight depends on the speed of the landing drum or conveyor.

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After web formation, consolidation of the web structure may be achieved using needle-punching.

The weight of the filtration media produced in accordance with the invention may be varied from approximately 200g/m² up to 1000g/m². For respiratory filter applications basis weights in the range 350-500g/m² would normally be selected.

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To improve or modify performance characteristics (eg flow resistance, filtration efficiency, dimensional stability and fluid transmission) ready-made fabrics, scrims or films can be attached to fabrics produced in accordance with the invention.

- 5 As mentioned above, the properties of the web formed in the process according to the invention are more isotropic than in the prior art. This may manifest itself in a lower ratio of the tensile strengths of the web in the machine and cross directions (MD:CD), ie the longitudinal and transverse directions of the web as it is manufactured. Thus, according to a second aspect of the invention there is
- 10 provided a filtration medium comprising a non-woven web of fibrous material, said web having an MD:CD ratio of less than 2:1. More preferably, the MD:CD ratio is less than 1.5:1.

- 15 Preferably, a blend of two or more types of fibre is used in the process of the invention. Most preferably, the blend comprises (a) a polyolefin and (b) an addition polymer comprising one or more halogen-substituted hydrocarbons. The former component of the blend is preferably polypropylene and the latter may be, for instance, polyvinylchloride or polyvinylidene chloride.

- 20 The blend may contain other fibres, either alternatively or in addition to those mentioned above. Examples of other fibre types which may be included are polyethylene and "modacrylic", ie a copolymer comprising from 35 to 85 weight percent acrylonitrile units and preferably having the balance made up substantially of other addition polymer-forming units, being halogenated hydrocarbon such as
- 25 vinyl chloride or vinylidene chloride.

- The components of the blend may be present in any suitable proportions. Preferably, the weight ratio of (a):(b) is in the range 70:30 to 30:70. Most preferably, the two classes of fibre are present in approximately equal proportions.
- 30 ie in each case between 45% and 55% by weight.

Preferably, the linear density of the two classes of the fibres in the blend is similar and is in the range 0.1 - 10 dtex (dtex = weight in grams of 10,000m of fibre).

Most preferably, the fibres are of less than 3.3 dtex. In terms of fibre diameter, the diameter is most preferably 12µm or less.

5 The fibres are preferably substantially free from any fibre finishes, oils or other extraneous matter prior to blending. Such chemicals are ideally removed from the fibres by an aqueous scouring process using a solution containing a synthetic detergent, sodium carbonate or a potassium carbonate solution. Other scouring regimes may also be suitable. The scouring process should be followed by thorough rinsing and drying stages prior to further processing.

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Likewise, all mechanical processing machinery must be thoroughly cleaned, preferably by chemical means, to remove all fibre finish, waxes, grease, anti-static agents or other chemical residues.

15 Currently preferred embodiments of the invention will now be described in greater detail, by way of illustration only, with reference to the accompanying drawings, in which

Figure 1 is a schematic diagram of a roller-based air-laying process; and

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Figure 2 is a schematic diagram of a sifting-based air-laying process.

Roller-Based Air-Laying

25 Roller-based systems can take many forms. A basic embodiment is illustrated in Figure 1. In a roller-based air-laying process raw fibres are transferred first from a feed conveyor 11 to a clothed feed roller system 12 and then to a rapidly rotating cylinder 13 which is clothed with teeth and interacts with fixed carding elements 14, 15 or some other clothed surface (eg clothed rollers). Electrostatic charging of
30 the fibres is achieved as the fibres are opened on the clothed cylinders 12, 13. An air knife 16 displaces fibres from the cylinder 13 on to a perforated conveyor 17 to which suction is applied from below. A non-woven web of fibre is built up on the

perforated conveyor 17 from which the web is drawn off and consolidated by needle-punching.

Sifting-Based Air-Laying

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An example of a sifting-based air-laying process is illustrated in Figure 2. In such a process, loose fibre is contained within a drum 21 having a grid 22 at its base. Rotors 23 within the drum 21 displace fibres in an air stream on to the top surface of a perforated conveyor 24, to which suction is applied from below. Again, the non-woven web is built up on the conveyor from which it is drawn off and consolidated by needle-punching. Airflow in the system is constrained between a pair of rollers 25,26, the downstream one of which 26 also applies compression to the web. Other systems that use rotating rollers or brushes instead of a static grid and rotors may also be used.

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Fibre Blends

Examples of fibre blends which may be used are:

- 20 a) Polyvinylchloride / Polypropylene
- b) Polyvinylchloride / Modacrylic / Polypropylene
- c) Polyvinylchloride / Polypropylene / Polyethylene
- 25 d) Polyvinylchloride / Modacrylic / Polyethylene

In each case, the proportion of PVC in the blend is approximately 50%. All the fibres have diameters of 12µm or less and lengths in the range 2 to 12mm.

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Experimental results have indicated that the method of the invention provides marked performance benefits in the filter media compared to the prior art:

(i) Up to a 20% reduction in the weight of the fabric can be achieved whilst maintaining a bacterial filtration efficiency of at least 99.9997%.

(ii) Up to a 39% reduction in the resistance to flow can be achieved (compared to the existing art) whilst maintaining a bacterial filtration efficiency of at least 99.9997%.

(iii) Bacterial filtration efficiencies of at least 99.99997% can be achieved with a single layer air-laid structure. No laminated or incorporated layers (eg meltblown fabrics) are required.

Typical results (resistance to flow and filtration efficiency) for fabrics produced using the method of the invention (specifically, the roller-based air-laying approach) are given in Table 1. These samples were a 50:50 blend of polyvinylchloride and polypropylene.

Table 1

Typical Test Results for Air-Laid Media

Sample ref	Fabric weight (g/m ²)	Resistance to flow @60 l/min (cmH ₂ O)	Bacterial Filtration Efficiency (%)
2E	402	1.4	99.9997
6C	433	1.8	99.9994
4E	463	1.6	99.9998
6B	491	2.1	99.999
4B	529	1.8	99.999
7A	597	2.1	>99.999991

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All tests were carried out on a pad of the respective fabric measuring 7.5x5.3cm and welded into a plastic housing with 22mm cylindrical inlet and outlet. Resistance to flow was measured in accordance with BS EN ISO 9360-1:2000. For bacterial efficiency, no standard currently exists. However, all products were

5 tested in accordance with the former draft standard prEN 13328-1 Part 1.